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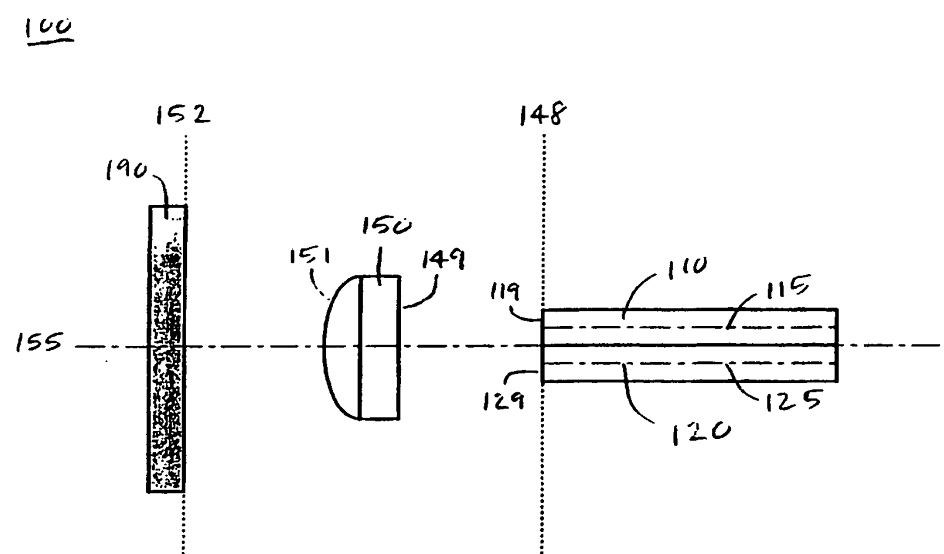
(54) Title: SINGLE LENS REFLECTIVE FIBER OPTIC COMPONENT GEOMETRY



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(57) Abstract: A single lens reflective fiber optic component geometry is described. The geometry uses a single lens to couple light from one or more input optical fibers to one or more optical output fibers via a reflective light processing element.

SINGLE LENS REFLECTIVE FIBER OPTIC COMPONENT GEOMETRY

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to fiber optic components. More particularly, the present invention relates to a geometry for single lens reflective fiber optic components.

Description of Related Art

Conventional fiber optic components which operate on expanded optical beams require two lenses, one to expand and collimate the light from the input optical fiber and a second lens to focus and couple the processed light reflected or transmitted from the light processing element into the output optical fiber. The use of two lenses requires sufficient space within the device to accommodate the two beam paths and, in the case of a reflective light processing element, does not facilitate a parallel input/output fiber geometry. Moreover, two-lens designs require complicated optical alignments between the fibers and their associated lenses and between these assemblies and the light processing element.

What is needed is a fiber optic component geometry with a reduced number of optical components. What is needed is a fiber optic component geometry which makes it easier and less expensive to build fiber optic components. What is needed is a fiber optic component geometry which allows the manufacture of more compact fiber optic components.

SUMMARY OF THE INVENTION

The present invention is directed towards a fiber optic component. The fiber optic component comprises an input optical fiber capable of carrying an optical beam, the input optical fiber having a input optical fiber longitudinal axis and an input optical fiber endface; a lens optically coupled to the input optical fiber, the lens capable of collimating the optical beam from the input

optical fiber, the lens having an optical axis and an input focal plane and an output focal plane; a reflective light processing element optically coupled to the lens, the reflective light processing element capable of reflecting substantially none to substantially all of the optical beam from the lens back through the lens, the reflective light processing element capable of modifying at least one characteristic of the optical beam, the reflective light processing element having a reflective surface; and an output optical fiber optically coupled to the lens, the output optical fiber having a output optical fiber longitudinal axis and an output optical fiber endface.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1A shows a side view of one embodiment of a fiber optic component having a single lens reflective fiber optic component geometry of the present invention.

FIGURES 1B-1C show operation of one embodiment of a fiber optic component having a single lens reflective fiber optic component geometry of the present invention.

FIGURES 2A-2B show perspective views of one embodiment of an optical attenuator having the single lens reflective fiber optic component geometry of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1A shows a side view of one embodiment of a fiber optic component 100 having a single lens reflective fiber optic component geometry of the present invention. Fiber optic component 100 may be an attenuator, filter, modulator, isolator, or other reflective fiber optic component.

Fiber optic component 100 includes one or more input optical fibers 110 each having a longitudinal axis 115 and a fiber endface 119, one or more output optical fibers 120 each having a longitudinal axis 125 and a fiber endface 129, a lens 150, and a reflective light processing element 190. Lens 150 may include an input focal plane 148, an input face 149, an output face 151, an output focal plane 151, and an optical axis 155. Lens 150 may be a plano-convex lens.

Alternatively, lens 150 may be a gradient index lens, a gradium lens, or an aspheric lens. Lens 150 may include antireflection coatings to reduce backreflections. Input focal plane 148 and input face 149 of lens 150 may be separated by a gap. A gap of equal or different size may also separate output face 151 and output focal plane 152 of lens 150. Reflective light processing element 190 may be a micromachined grating modulator, micromachined tilting mirror, or filtering element. Input and output optical fibers 110 and 120 may be aligned with the longitudinal axis of a micromachined grating modulator in order to minimize shadowing effects and backreflections.

Input optical fiber 110 is optically coupled to lens 150. Lens 150 is optically coupled to reflective light processing element 190. Lens 150 is also optically coupled to output optical fiber 120. Input optical fiber 110 and output optical fiber 120 may be positioned adjacent to one another and aligned with respect to each other so that their longitudinal axes 115 and 125 are parallel. Input optical fiber 110 and output optical fiber 120 may be positioned in front of lens 150 so that their longitudinal axes 115 and 125 are symmetric about an optical axis 155 of lens 150.

Input optical fiber 110 and output optical fiber 120 may also be positioned so that their fiber endfaces 119 and 129 lie in the same plane. Fiber endfaces 119 and 129 may also be positioned at an input focal plane 148 of lens 150. Fiber endfaces 119 and 129 may be beveled or angle polished, or include antireflection coatings to reduce backreflections.

Reflective light processing element 190 may be positioned at an output focal plane 152 of lens 150. Reflective light processing element 190 may be oriented normal to optical axis 155 of lens 150.

FIGURES 1B-1C show operation of one embodiment of a fiber optic component 100 having a single lens reflective fiber optic component geometry of the present invention.

An optical beam 160 travels through input optical fiber 110, exits through endface 119, and travels through lens 150. Optical beam 160 is collimated by lens 150 and focused onto reflective light processing element 190. Optical beam 160 may form planar wavefronts 160' as it exits lens 150. Planar

wavefronts 160' of the collimated optical beam 160 may exit lens 150 at a small angle θ. Planar wavefronts 160' are reflected off of reflective light processing element 190. Substantially all, substantially none, or a portion of each planar wavefront 160' may be focused by lens 150 onto fiber endface 129 of output optical fiber 120. Optical beam 160 may be thus be attenuated, filtered, modulated, isolated, or otherwise modified when it is reflected off of reflective light processing element 190 and back through lens 150.

By placing reflective light processing element 190 at output focal plane 152 of lens 150, optical beam 160 exits lens 150 substantially parallel to optical axis 155 of lens 150 and may be reflected substantially collinear with longitudinal axis 125 of output fiber 120.

For the geometry shown and in the absence of lens aberrations, optical beam 160 will be substantially collinear with longitudinal axis 125 of output optical fiber 120 for any separation distance between input and output optical fibers 110 and 120. This simplifies the device fabrication procedure by allowing the optical alignment to be accomplished in a single step. Input and output optical fibers 110 and 120 may be held together, for example in a silicon V-groove block or a two hole ferrule, and then actively aligned with a reflective light processing element 190 / lens 150 assembly so that their longitudinal axes 115 and 125 are positioned symmetrically about optical axis 155 of lens 150 and so that their fiber endfaces 119 and 129 are positioned in input focal plane 148 of lens 150. In addition, slight angular misalignments between reflective light processing element 190 and lens 150 can be compensated for by offsetting the fiber pair from optical axis 155 of lens 150.

The alignment process during manufacture of fiber optic component 100 may involve first aligning light processing element 190 with lens 150 before aligning input and output optical fibers 110 and 120 with the light processing element 190 / lens 150 assembly. Alternatively, other alignment processes may be used such as first aligning input and output optical fibers 110 and 120 with lens 150 before aligning the input and output optical fibers 110 and 120 / lens 150 assembly with light processing element 190.

FIGURES 2A-2B show perspective views of one embodiment of an optical attenuator 200 having the single lens reflective fiber optic component geometry of the present invention. FIGURE 2A shows operation of optical attenuator 200 in the minimum attenuation mode. Substantially all of each planar wavefront 160' incident on reflective light processing element 190 is reflected back through lens 150 and focused onto endface 129 of output optical fiber 120. FIGURE 2B shows operation of optical attenuator 200 in the maximum attenuation mode. Substantially none of each planar wavefront 160' incident on reflective light processing element 190 is reflected away from lens 150, and so substantially none of the optical beam 160 reaches output optical fiber 120.

Advantages of the single lens reflective fiber optic component geometry of the present invention over two-lens designs include: (1) a reduced number of parts; (2) easier manufacture process; and (3) a more compact design.

This fiber optic component geometry requires a reduced number of internal components. Only a single lens with a support structure is needed. With a reduced number of parts comes a correspondingly simpler, lower cost assembly process. The optical alignment steps required to fabricate the device are simpler as compared to two-lens designs. The input and output optical fibers may be fixed relative to each other before the alignment step and then positioned at the correct location in front of the lens as a single unit. By placing the light processing element at the output focal plane of the lens, improved fiber coupling efficiency may be achieved when the input and output fibers are themselves parallel, thus simplifying the device fabrication process and facilitating parallelism between the input and output ports of the packaged device.

This fiber optic geometry is well suited for space efficient packaging. Input and output optical fibers may be selected with small diameters, enabling them to be closely spaced in front of the lens and minimizing the spatial separation of the incident and reflected collimated beams and consequently the size of each individual fiber optic component. With the input and output beam paths being nearly collinear, multiple fiber optic components may be housed in

a single package without increasing the height of the package. This provides a housing in a package of small footprint and which is compatible with conventional circuit board mounting.

While the invention has been described in terms of some specific examples and in some specific embodiments, it will be clear that this invention is not limited to these specific examples and embodiments and that many changes and modified embodiments will be obvious to those skilled in the art without departing from the true spirit and scope of the invention as defined in the appended claims.

What is claimed is:

CLAIMS

1. A fiber optic component, comprising:

an input optical fiber capable of carrying an optical beam, the input optical fiber having an input optical fiber longitudinal axis and an input optical fiber endface;

a lens optically coupled to the input optical fiber, the lens capable of collimating the optical beam from the input optical fiber, the lens having an optical axis and an input focal plane and an output focal plane;

an output optical fiber optically coupled to the lens, the output optical fiber having an output optical fiber longitudinal axis and an output optical fiber endface; and

a micromechanical active device optically coupled to the lens, the micromechanical active device capable of controllably reflecting substantially none to substantially all of the optical beam from the input optical fiber through the lens, back through the lens and into the output optical fiber, the micromechanical active device capable of modifying at least one characteristic of the optical beam, the micromechanical active device having a reflective surface.

2. The fiber optic component of claim 1, wherein the input optical fiber is positioned adjacent and substantially parallel to the output optical fiber.

3. The fiber optic component of claim 1, wherein the input optical fiber is positioned at an angle with respect to the output optical fiber.

4. The fiber optic component of claim 1, wherein the input optical fiber endface and the output optical fiber endface are positioned substantially at the input focal plane of the lens.

5. The fiber optic component of claim 1, wherein the input optical fiber endface and the output optical fiber endface are substantially coplanar.

6. The fiber optic component of claim 1, wherein the input optical fiber longitudinal axis and output optical fiber longitudinal axis are positioned substantially symmetrically about the optical axis of the lens.

7. The fiber optic component of claim 1, wherein the input optical fiber longitudinal axis and output optical fiber longitudinal axis are positioned substantially parallel to the optical axis of the lens.

8. The fiber optic component of claim 1, wherein the input optical fiber longitudinal axis and output optical fiber longitudinal axis are positioned at an angle with respect to the optical axis of the lens.

9. The fiber optic component of claim 1, wherein the micromechanical active device is positioned substantially at the output focal plane of the lens.

10. The fiber optic component of claim 1, wherein the reflective surface of the micromechanical active device is positioned substantially perpendicular to the optical axis of the lens.

11. The fiber optic component of claim 1, wherein the lens is a plano-convex lens.

12. The fiber optic component of claim 1, wherein the lens is a gradient index lens.

13. A fiber optic component, comprising:

an input optical fiber capable of carrying an optical beam, the input optical fiber having an input optical fiber longitudinal axis and an input optical fiber endface;

a lens optically coupled to the input optical fiber, the lens capable of collimating the optical beam from the input optical fiber, the lens having an optical axis and an input focal plane and an output focal plane;

an output optical fiber optically coupled to the lens, the output optical fiber having an output optical fiber longitudinal axis and an output optical fiber endface; and

a micromechanical active device optically coupled to the lens, the micromechanical active device capable of attenuating the optical beam by controllably reflecting substantially none to substantially all of the optical beam from the input optical fiber through the lens, back through the lens and into the output optical fiber, the micromechanical active device having a reflective surface.

14. The fiber optic component of claim 13, wherein the input optical fiber is positioned adjacent and substantially parallel to the output optical fiber.

15. The fiber optic component of claim 13, wherein the input optical fiber is positioned at an angle with respect to the output optical fiber.

16. The fiber optic component of claim 13, wherein the input optical fiber endface and the output optical fiber endface are positioned substantially at the input focal plane of the lens.

17. The fiber optic component of claim 13, wherein the input optical fiber endface and the output optical fiber endface are substantially coplanar.

18. The fiber optic component of claim 13, wherein the input optical fiber longitudinal axis and output optical fiber longitudinal axis are positioned substantially symmetrically about the optical axis of the lens.

19. The fiber optic component of claim 13, wherein the input optical fiber longitudinal axis and output optical fiber longitudinal axis are positioned substantially parallel to the optical axis of the lens.

20. The fiber optic component of claim 13, wherein the input optical fiber longitudinal axis and output optical fiber longitudinal axis are positioned at an angle with respect to the optical axis of the lens.

21. The fiber optic component of claim 13, wherein the micromechanical active device is positioned substantially at the output focal plane of the lens.

22. The fiber optic component of claim 13, wherein the reflective surface of the reflective light processing element is positioned substantially perpendicular to the optical axis of the lens.

23. The fiber optic component of claim 13, wherein the lens is a plano-convex lens.

24. The fiber optic component of claim 13, wherein the lens is a gradient index lens.

25. A method for modulating an optical beam, comprising:

carrying an optical beam from a source to a lens, the source being optically coupled to the lens;

collimating the optical beam with the lens;

focusing the optical beam onto a micromechanical active device with the lens, the lens being optically coupled to the micromechanical active device;

modulating the optical beam by controlling the micromechanical active device to controllably reflect substantially none to substantially all of the optical beam back through the lens; and

focusing the optical beam with the lens.

26. The method of claim 25, wherein the source is an input optical fiber.

27. The method of claim 25, wherein the lens is a plano-convex lens.

28. The method of claim 25, wherein the lens is a gradient index lens.

29. A fiber optical component, comprising:

an input optical fiber capable of carrying an optical beam, the input optical fiber having an input optical fiber longitudinal axis and an input optical fiber endface;

a lens optically coupled to the input optical fiber, the lens capable of collimating the optical beam from the input optical fiber, the lens having an optical axis and an input focal plane and an otput focal plane;

an output optical fiber optically coupled to the lens, the output optical fiber having an output optical fiber longitudinal axis and an output optical fiber endface; and

a micromachined grating modulator optically coupled to the lens, the micromachined grating modulator capable of controllably reflecting substantially none to substantially all of the optical beam from the input optical fiber through the lens, back through the lens and into the output optical fiber, the micromachined grating modulator capable of modifying at least one characteristic of the optical beam, the micromachined grating modulator having a reflective surface.

30. A fiber optical component, comprising:

an input optical fiber capable of carrying an optical beam, the input optical fiber having an input optical fiber longitudinal axis and an input optical fiber endface;

a lens optically coupled to the input optical fiber, the lens capable of collimating the optical beam from the input optical fiber, the lens having an optical axis and an input focal plane and an output focal plane;

an output optical fiber optically coupled to the lens,the output optical fiber having an output optical fiber longitudinal axis and an output optical fiber endface; and

a micromachined tilting mirror optically coupled to the lens, the micromachined tilting mirror capable of controllably reflecting substantially none to substantially all of the optical beam from the input optical fiber through the lens, back through the lens and into the output optical fiber, the micromachined tilting mirror capable of modifying at least one characteristic of the optical beam, the micromachined tilting mirror having a reflective surface.

31. A method for modulating an optical beam, comprising:

carrying an optical beam from a source to a lens, the source being optically coupled to the lens;

collimating the optical beam with the lens;

focusing the optical beam onto a micromachined tilting mirror with the lens, the lens being optically coupled to the micromachined tilting mirror;

modulating the optical beam by controlling the micromachined tilting mirror to controllably reflect substantially none to substantially all of the optical beam back through the lens; and

focusing the optical beam with the lens.

32. A method for modulating an optical beam, comprising:

carrying an optical beam from a source to a lens, the source being optically coupled to the lens;

collimating the optical beam with the lens;

focusing the optical beam onto a micromachined grating modulator with the lens, the lens being optically coupled to the micromachined grating modulator;

modulating the optical beam by controlling the micromachined grating modulator to controllably reflect substantially none to substantially all of the optical beam back through the lens; and

focusing the optical beam with the lens.

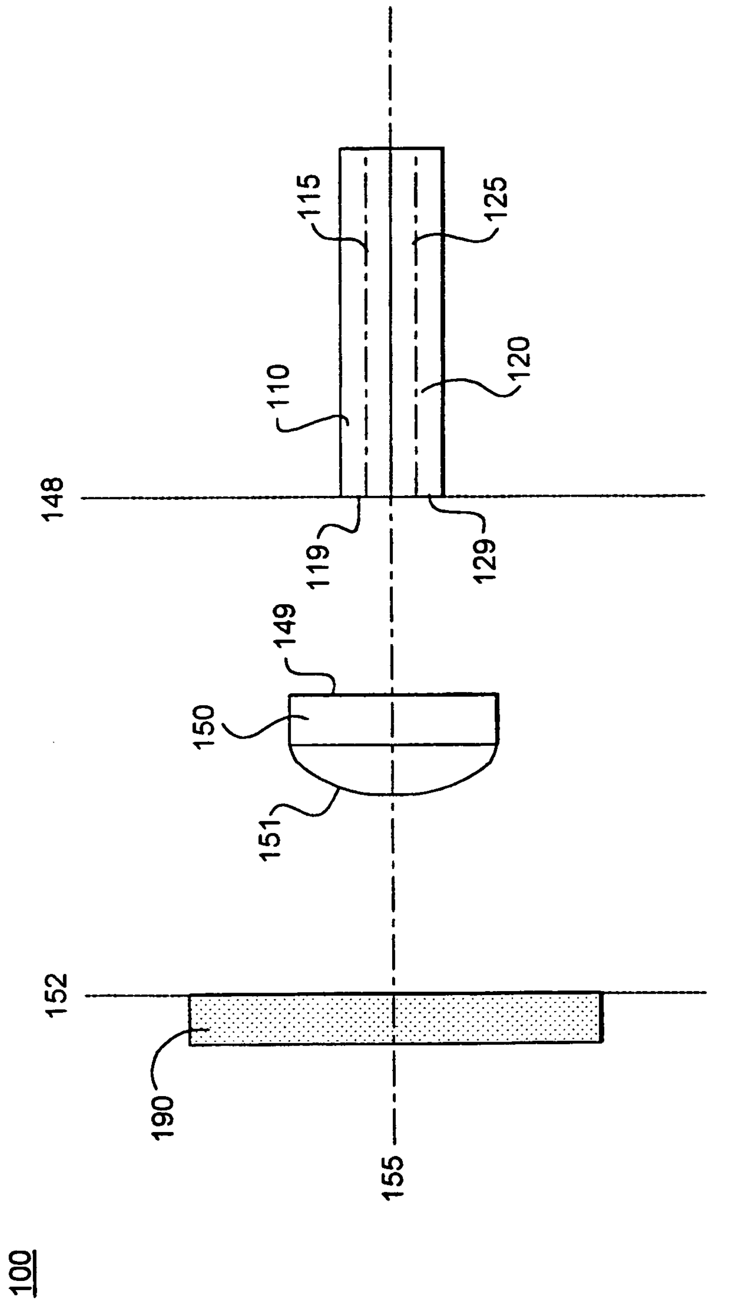

FIG. 1A

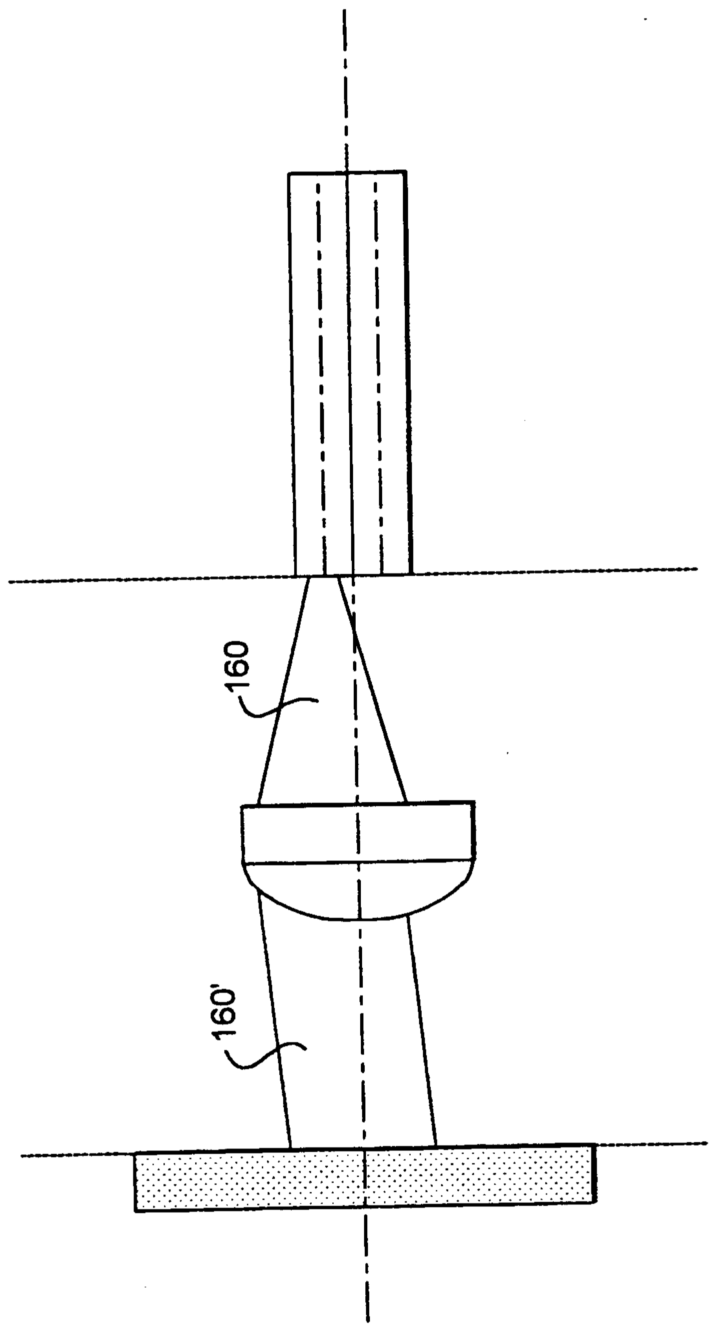

FIG. 1B

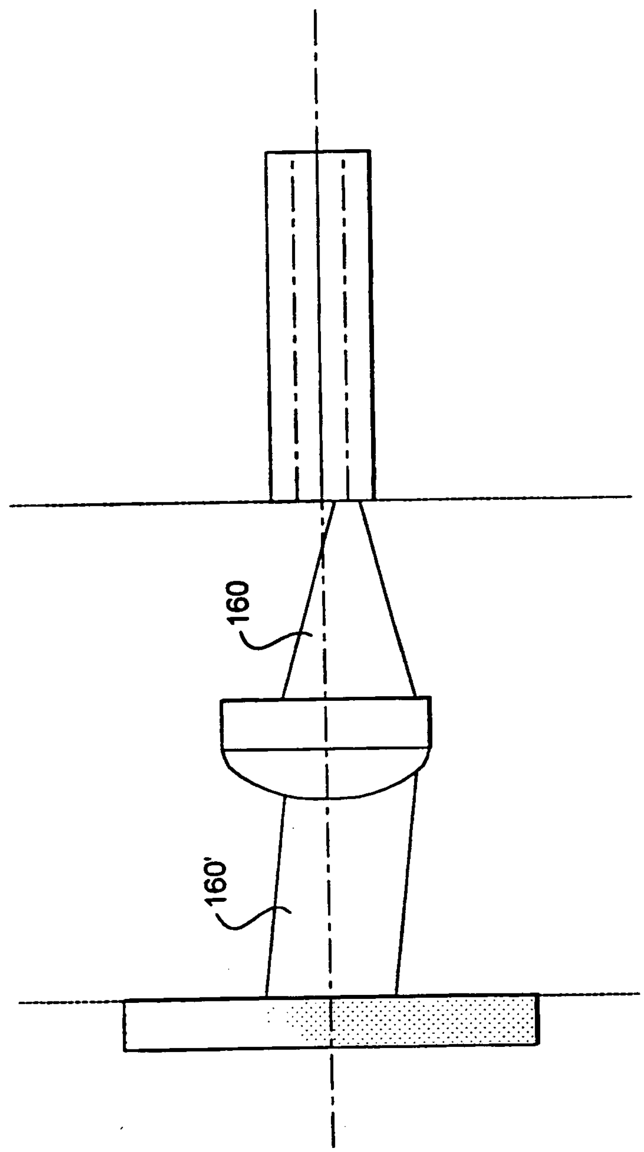

FIG. 1C

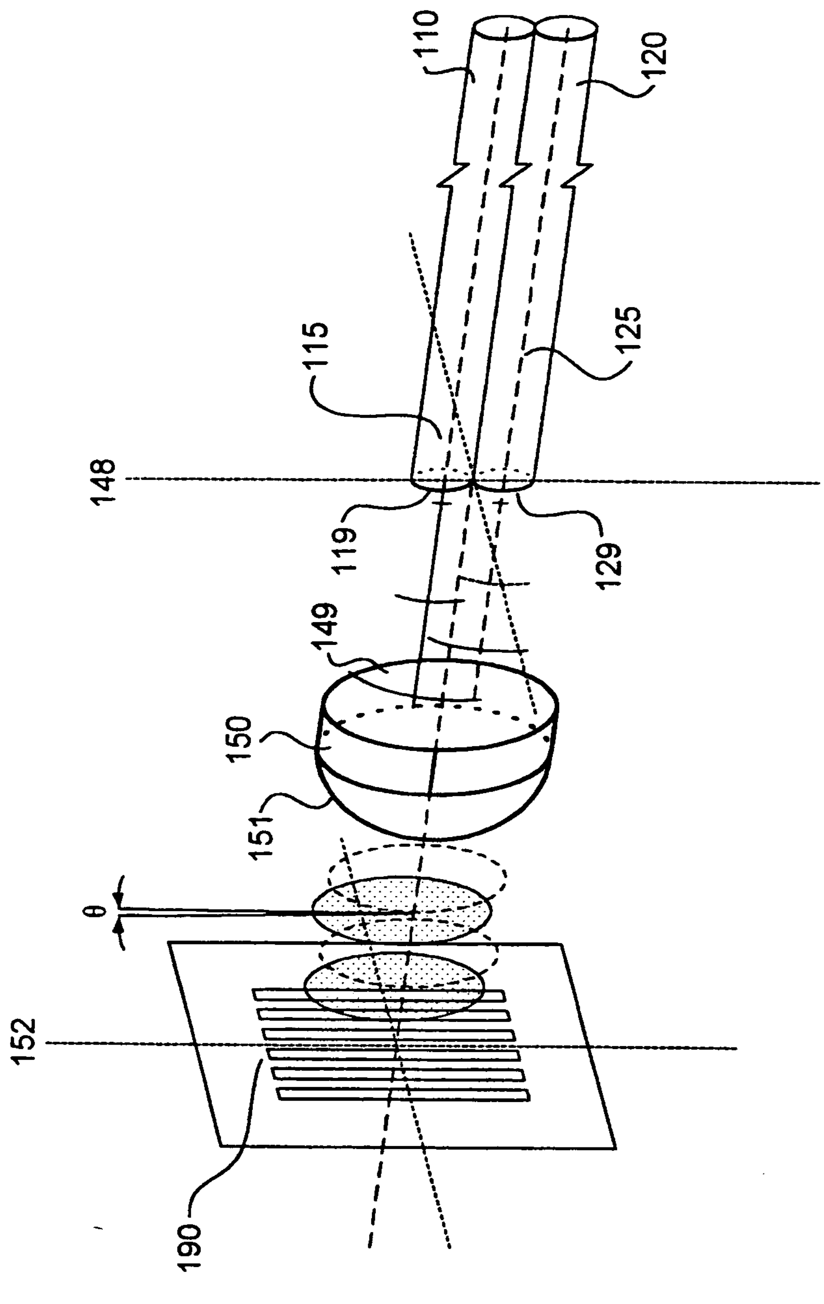

FIG. 2A

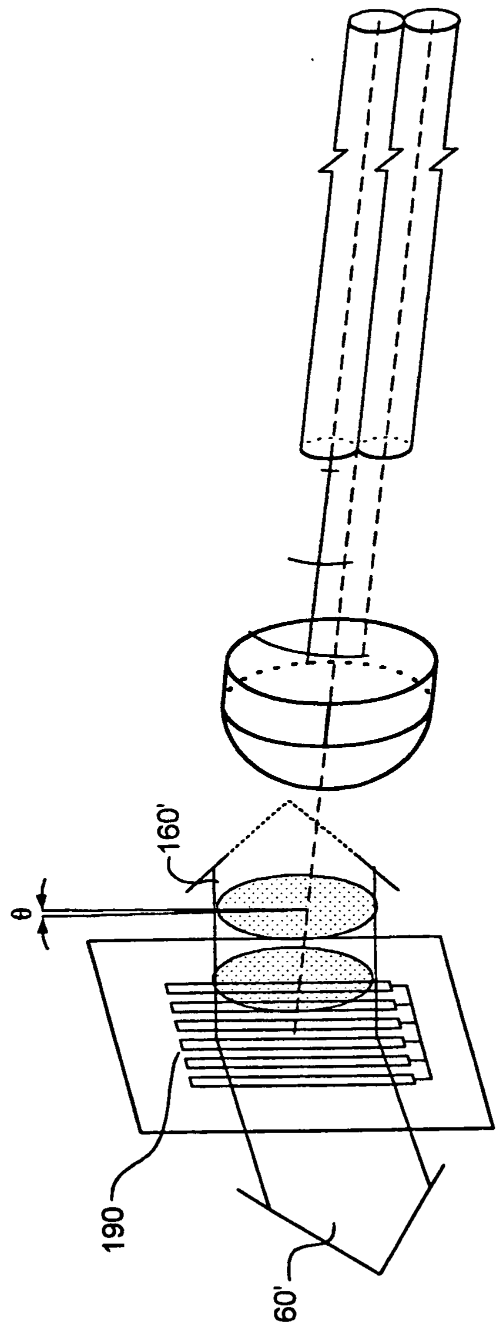

FIG. 2B

INTERNATIONAL SEARCH REPORT

Intern ...al Application No
PCT/US 00/21665

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B26/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, IBM-TDB, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 900 983 A (GOOSSEN KEITH WAYNE ET AL) 4 May 1999 (1999-05-04)	1,2,4,5, 9,10,13, 14,16, 17,21,22
Y	abstract; figures 2B-3D column 6, line 21-40	1,3,8, 29,32

X	US 4 626 066 A (LEVINSON FRANK H) 2 December 1986 (1986-12-02) abstract; figures 3-6 column 3, line 11-63	1,2,4,5, 9,10,30, 31

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
14 December 2000	27/12/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern   .al Application No
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Intern. ial Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 004, no. 146 (P-031), 15 October 1980 (1980-10-15) & JP 55 095909 A (FUJITSU LTD), 21 July 1980 (1980-07-21) abstract; figures 1,3,4 ---	1,3,8
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EPM TC 2800
FINAL SEARCH DATE
DELIVER TO GOV'T DATE

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